Claims

[c1] 1.A method for determining at least one of past-service conditions and remaining useful life of at least one of a component of a combustion engine and a thermal barrier coating thereof, said method comprising:
(1)providing a combustion-engine component comprising a thermal barrier coating that comprises at least one photoluminescent ("PL") material that can be excited by a first radiation at a first wavelength range and emits a second radiation at a second wavelength range different from said first wavelength range in response to said first radiation; said second radiation having a characteristic property that correlates with an amount of a crystalline phase in said thermal barrier coating, which amount changes as said combustion-engine component is exposed to elevated temperatures;
(2)directing said first radiation having said first wavelength range at said thermal barrier coating of said combustion-engine component;
(3)measuring said characteristic property of said second radiation;
(4)determining said amount of said crystalline phase present in said thermal barrier coating from said characteristic property of said second radiation; and
(5)determining at least one of past-service conditions and remaining useful life of at least one of said component of said combustion engine and said thermal barrier coating thereof from said amount of said crystalline phase.

[c2] 2.The method according to claim 1, wherein said thermal barrier coating comprises zirconia stabilized with at least one material selected from the group consisting of yttria, yttrium aluminum oxide garnet, calcia, magnesia, india, scandia, and ytterbia.

[c3] 3.The method according to claim 1, wherein said thermal barrier coating comprises a material selected from the group consisting of yttria-stabilized zirconia and yttria-partially-stabilized zirconia.

[c4] 4.The method according to claim 3, wherein yttria is present at an amount from about 6 to about 8 weight percent of said thermal barrier coating.

[c5] 5.The method according to claim 1, wherein said PL material is yttria doped with at least one a rare-earth metal ion.

[c6] 6.The method according to claim 2, wherein said at least one material is doped with at least one rare-earth metal selected from the group consisting of europium, samarium, terbium, dysprosium, erbium, praseodymium, gadolinium, holmium, and thullium.

[c7] 7.The method according to claim 5, wherein said rare-earth metal is europium.

[c8] 8.The method according to claim 1, wherein said first wavelength range is an ultraviolet range.

[c9] 9.The method according to claim 1, wherein said first wavelength range is a visible light less than about 450 nm.

[c10] 10.The method according to claim 1, wherein said second radiation is a visible light.

[c11] 11.The method according to claim 1, wherein said second radiation is a near IR radiation.

[c12] 12.The method according to claim 1, wherein said crystalline phase is a monoclinic phase.

[c13] 13.The method according to claim 12, wherein said characteristic property is an intensity of a peak at about 615 nm in an emission spectrum.

[c14] 14.The method according to claim 12, wherein the step of determining said amount of said crystalline phase comprises correlating a ratio of intensities of peaks at about 615 nm and about 605 nm with known amount of the monoclinic phase.

[c15] 15.The method according to claim 1, wherein the step of determining at least one of past-service conditions and remaining useful life of at least one of said component of said combustion engine and said thermal barrier coating comprises correlating said amount of said crystalline phase with data selected from the group consisting of known historical temperature and time to failure of an engine component.

[c16] 16.A method for determining at least one of past-service conditions and

remaining useful life of at least one of a component of a combustion engine and a thermal barrier coating thereof, said method comprising:
(1)providing a combustion-engine component comprising a thermal barrier coating that comprises at least two PL materials that can be excited by a first radiation at a first wavelength range and emits at least a second radiation in a second wavelength range different from said first wavelength range in response to said first radiation, said second radiation emitted by each of said PL materials having a different characteristic property attributable to each of said PL materials, said characteristic property correlating with an amount of a crystalline phase in said thermal barrier coating, which amount increases as said combustion-engine component is exposed to elevated temperatures;
(2)directing said first radiation having said first wavelength range at said thermal barrier coating of said combustion-engine component;
(3)measuring said characteristic property of said second radiation;
(4)determining said amount of said crystalline phase present in said thermal barrier coating from said characteristic property of said second radiation;
(5)determining a remaining amount of said thermal barrier coating; and
(6)determining at least one of past-service conditions and remaining useful life of at least one of said component of said combustion engine and said thermal barrier coating thereof from said amount of said crystalline phase and said remaining amount of said thermal barrier coating.

[c17]

17.An apparatus for determining at least one of past-service conditions and remaining useful life of at least one of a component of a combustion engine and a thermal barrier coating thereof, said apparatus comprising:
(1)a source of first radiation having a first wavelength range, said first radiation being directed at said thermal barrier coating that comprises at least one PL material capable of emitting a second radiation having a second wavelength range in response to an excitation by said first radiation;
(2)a radiation detector being capable of detecting said second radiation and being disposed to receive and measure a characteristic property thereof; and
(3)means for relating said characteristic property of said second radiation to one of an amount of a crystalline phase in said thermal barrier coating, past-service

conditions, and remaining useful life of said combustion-engine component.

[c18] 18.The apparatus according to claim 17, wherein said thermal barrier coating comprises zirconia stabilized with at least one material selected from the group consisting of yttria, yttrium aluminum oxide garnet, calcia, magnesia, india, scandia, and ytterbia.

[c19] 19.The apparatus according to claim 17, wherein said thermal barrier coating comprises a material selected from the group consisting of yttria-stabilized zirconia and yttria-partially-stabilized zirconia.

[c20] 20.The apparatus according to claim 19, wherein yttria is present at an amount from about 6 to about 8 weight percent of said thermal barrier coating.

[c21] 21.The apparatus according to claim 17, wherein said PL material is yttria doped with at least one a rare-earth metal ion.

[c22] 22.The apparatus according to claim 18, wherein said at least one material is doped with at least one rare-earth metal selected from the group consisting of europium, samarium, terbium, dysprosium, erbium, praseodymium, gadolinium, holmium, and thullium.

[c23] 23.The apparatus according to claim 21, wherein said rare-earth metal is europium.

[c24] 24.The apparatus according to claim 17, wherein said first wavelength range is an ultraviolet range.

[c25] 25.The apparatus according to claim 17, wherein said first wavelength range is a visible light less than about 450 nm.

[c26] 26.The apparatus according to claim 17, wherein said second radiation is a visible light.

[c27] 27.The apparatus according to claim 17, wherein said second radiation is a near IR radiation.

[c28] 28.The apparatus according to claim 17, wherein said crystalline phase is a

monoclinic phase.

[c29] 29.The apparatus according to claim 28, wherein said characteristic property is the intensity of a peak at about 615 nm in an emission spectrum.

[c30] 30.The apparatus according to claim 17, wherein said radiation detector is a spectrophotometer.

[c31] 31.The apparatus according to claim 28, wherein said relating said characteristic property of said second radiation to said amount of said crystalline phase comprises correlating a ratio of intensities of peaks at about 615 nm and about 605 nm with known amount of the crystalline phase.

[c32] 32.The apparatus according to claim 28, wherein said relating said characteristic property of said second radiation to said past-service conditions comprises correlating a ratio of intensities of peaks at about 615 nm and about 605 nm with known temperatures to which said engine component has been exposed.

[c33] 33.The apparatus according to claim 28, wherein said relating said characteristic property of said second radiation to said remaining useful life of said engine component comprises correlating a ratio of intensities of peaks at about 615 nm and about 605 nm with a known time to failure of said engine component.

[c34] 34.A thermal barrier coating on an engine component, said thermal barrier coating comprising zirconia and at least one metal oxide that is capable of retarding a formation of a zirconia monoclinic phase when said engine component is exposed to elevated temperatures, said at least one metal oxide being doped with at least one metal ion that is excitable by a first radiation having a first wavelength range and emits a second radiation having a second wavelength range in response to an excitation by said first radiation, a spectrum of said second radiation having a characteristic property that is identifiable with and quantifiable in relation to an amount of the zirconia monoclinic phase.

[c35] 35.A thermal barrier coating on an engine component, said thermal barrier

coating consisting essentially of zirconia and at least one metal oxide that is capable of retarding a formation of a zirconia monoclinic phase when said engine component is exposed to thermal cycling, said at least one metal oxide being doped with at least one metal ion that is excitable by a first radiation having a first wavelength range and emits a second radiation having a second wavelength range in response to an excitation by said first radiation, a spectrum of said second radiation having an characteristic property that is identifiable with and quantifiable in relation to an amount of the monoclinic phase; wherein said at least one metal oxide is selected from the group consisting of yttrium aluminum oxide garnet, calcia, magnesia, india, scandia, and ytterbia.

[c36] 36.The thermal barrier coating on an engine component according to claim 35, wherein said at least one metal ion is selected from the group consisting of rare-earth metal ions.